V. Twersky ②

FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

Ocean Acoustics Program
Dr. Marshall Orr, Director
Code 1125 0A
Arlington, Virginia 22217-5000

Submitted by

Principal Investigator: Dr. Victor Twersky, (312) 996-8773
Social Security No. 088-18-6991
Department of Mathematics,
Statistics, and Computer Science

University of Illinois at Chicago
Box 4348, Chicago, Illinois 60680

for research on

UNDERWATER SCATTERING OF SOUND

Contract N00014-82-K-0108 (continuing as Grant N0014-90-J-1041)

Duration: December 16, 1981 - June 15, 1990

V. Twersky

UNDERWATER SCATTERING OF SOUND

Final Report for Contract N0014-82-0108 (continuing as Grant N0014-90-J-1041)

Objective

To further the understanding of volume and surface scattering effects on propagation.

Background

Scattering by distributions of discrete irregularities in the sea volume, and on its surface and bottom, influence propagation phenomena basic to underwater communication and allied programs. To isolate essential aspects, key surface and volume distributions were investigated.

Approach

Analytical and numerical, leading to simplified theory to clarify the essential physics and facilitate measurement and inversion of data.

Summary of results

The attached numbered list of twenty-three titles indicates the principal research results.

This research deals with sea surface, seabottom, and sea volume effects on propagation that can be analyzed in terms of scattering by statistical distributions of discrete irregularities (e.g., ridges on a surface, or particles in a medium). The irregularities exist in the sea surface (topped by an air or ice cover), the sea volume, and in the seabottom.

The gross physical properties for coherent propagation of sound are represented by bulk physical parameters and surface impedances determined by averaging the field over the ensemble of statistical distributions of the irregularities (their shapes, sizes, physical parameters, locations, separations, etc). In general, the first approximation for the coherent field (the average wave) corresponds to phase and absorptive effects. Fluctuations with respect to average values lead to incoherent scattering, and to the associated attenuation

of the coherent wave. In addition to obtaining more complete results for the coherent wave for key statistical problems, simplified forms for the incoherent scattering were also developed.

The chronological list of publications consists of essentially three sets of articles: one on rough surfaces (1, 2, 6, 9, 10, 12, 16, 19), one on random volume distributions (3, 5, 7, 8, 11, 13, 15, 17, 21, 22, 23), and one deals with single obstacles or regular collections that can be analyzed as a single obstacle (3, 14, 18, 20).

Articles (1) and (2) develop the general theory for reflection and scattering by correlated rough surface distributions, (9) and (16) apply the theory to low and high frequency scattering by ellipsoidal roughness elements, and (19) generalizes the high frequency results to multicomponent distributions. Articles (6, 10, 12) develop a uniform asymptotic theory for point-source excitation, and apply the results to invert and interpret Medwin's laboratory measurements at near-grazing observation.

Article (4) investigates propagation in correlated volume distribution of obstacles with minimum separation of particles large compared to wavelength, and (5, 7, 8, 11) consider separation small compared to wavelength. Dispersion (wavelength-dependent) terms of the bulk parameters, and for the attenuation arising from incoherent scattering, are obtained for all fields of interest to ocean physics. Article (13) considers low frequency incoherent scattering (and the associated coherent attenuation) for correlated low-refracting nonspherical particles averaged over orientation, and (17) generalizes the theory to mixtures of different sized particles as well as to polydisperse distributions. Articles (13, 17), which apply for scattering by biostructures in the ocean, were tested in detail by inverting (15, 21) Shung's laboratory data for ultrasonic scattering by suspensions of red blood cells under different flow conditions. Articles (22, 23) relate to underwater propagation in relatively densely packed bubble regions.

Article (4) develops general theory for scattering and non-scattering obstacles, (14) considers scattering by an obstacle near a penetrable interface, and (18, 20) consider regular arrays of resonant obstacles.

Work in progress on the continuing grant (90-J-1041), based on the results in (23), deals with slab region distributions of resonant obstacles, and with such slab regions bordering a sea-air or a sea-bottom interface.

PUBLICATIONS ACKNOWLEDGING ONR SUPPORT FROM 1983 TO DATE

1. V. Twersky, "Multiple scattering of sound by correlated monolayers," J. Acoust. Soc. Am. **73**, 68-84 (1983).

2. V. Twersky, "Reflection and scattering of sound by correlated rough surfaces," J. Acoust. Soc. Am. **73**, 85-94 (1983).

3. V. Twersky, "Propagation in correlated distributions of large-spaced scatterers", J. Opt. Soc. Am. **73**, 313-320 (1983).

4. V. Twersky, "Scattering and non-scattering obstacles," SIAM J. Appl. Math. **43**, 711-725 (1983).

5. V. Twersky, "Wavelength-dependent refractive and absorptive terms for propagation in small-spaced correlated distributions," J. Opt. Soc. Am. **73**, 1562-1567 (1983).

6. R.J. Lucas and V. Twersky, "Coherent response to a point source irradiating a rough plane," J. Acoust. Soc. Am., **76**, 1847-1863 (1984).

7. V. Twersky, "Wavelength-dependent bulk parameters for coherent sound in correlated distributions of small-spaced scatterers," J. Acoust. Soc. Am. **77**, 29-37 (1985).

8. V. Twersky, "Wavelength-dependent electromagnetic parameters for coherent propagation in correlated distributions of small-spaced scatterers," J. Math. Phys. **26**, 2209-2217 (1985).

9. R.J. Lucas and V. Twersky, "Low-frequency reflection and scattering by ellipsoidally embossed surfaces," J. Acoust. Soc. Am., **78**, 1838-1850 (1985).

10. R.J. Lucas and V. Twersky, "Inversion of data for near grazing propagation over rough surfaces," J. Acoust. Soc. Am. **80**, 1459-1472 (1986).

11. V. Twersky, "Dispersive bulk parameters for coherent propagation in correlated random distributions," pp. 293-309 in Random Media, edited by G. Papanicolaou, Springer-Verlag, Berlin. 1987.

12. R.J. Lucas and V. Twersky, "Inversion of data for near grazing propagation over gravelled surfaces," J. Acoust. Soc. Am. **81**, 619-623 (1987).

13. V. Twersky, "Low-frequency scattering by correlated distributions of randomly oriented particles," J. Acoust. Soc. Am. **81**, 1609-1618 (1987).

14. R. Solakiewicz, "Scattering by an obstacle in a half-space bounded by a penetrable interface," Ph.D. Thesis, University of Illinois, Chicago, May, 1987.

15. R.J. Lucas and V. Twersky, "Inversion of ultrasonic scattering data for red block cell suspensions under different flow conditions, J. Acoust. Soc. Am. **82**, 794-799 (1987).

16. R.J. Lucas and V. Twersky, "High-frequency reflection and scattering by ellipsoidally embossed surfaces"; J. Acoust. Soc. Am. **83**, 2005-2011 (1987).

17. V. Twersky, "Low-frequency scattering by mixtures of correlated non-spherical particles," J. Acoust. Soc. Am. **84**, 409-415 (1988).

18. V. Twersky, "Multiple scattering by finite regular arrays of resonators," J. Acoust. Soc. Am. **87**, 25-40 (1990).

19. R.J. Lucas and V. Twersky, "High-frequency reflection and scattering by multi-component rough surface distributions," J. Acoust. Soc. Am.; to appear in May 1990.

20. V. Twersky, "Regular polygonal arrays of resonant scatterers;" submitted for publication.

21. R.J. Lucas and V. Twersky, "Inversion of ultrasonic scattering data for correlated mixtures of red blood cells;" submitted for publication.

22. N.E. Berger and V. Twersky, "Moments of the Percus-Yevick hard sphere correlation function;" submitted for publication.

23. N.E. Berger and V. Twersky, "Coherent propagation of sound in correlated distributions of resonant obstacles;" submitted for publication.